

Dynamic Pressure Reducer Control Refinement

Propellant Supply Control

Student



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Introduction: The Propellant Supply System (PSS) of the ASTERIA student rocket delivers pressurant from a high-pressure storage tank to the propellant tanks, which are connected via piping to the injector. At the injector, the propellant is fed into the combustion chamber. A Dynamic Pressure Reducer (DPR) is controlled to reduce and actively regulate the high upstream pressurant pressure to a defined downstream pressure level in the tank, which directly influences the pressure at the injector. The DPR is an on off solenoid valve. The injector pressure determines the mass flow, which is used to throttle the engine thrust. This regulation must be achieved under high operating pressures of up to 300 bar and fast transient conditions, posing significant challenges for system modeling and control. This thesis investigates the modeling, control, and experimental validation of the DPR used within the PSS of ASTERIA.

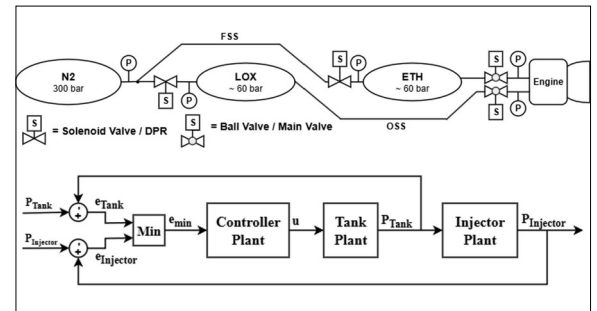
Approach: A combined modeling approach is applied, consisting of both physics-based and data-driven models of the PSS. The whitebox model is constructed from the governing gas dynamic and mass balance equations and is parametrized using component specifications and experimental data. The corresponding Simulink model is shown in Figure 2. In parallel, blackbox models are identified from test measurements and verified against data sets to assess their accuracy. The models are first evaluated in simulation to analyze their ability to reproduce the measured system behavior, this can be observed in Figure 3 (top). Based on the observed system dynamics and the characteristics of the actuator (DPR), two control approaches are implemented and tested: a bang-bang controller and a proportional-derivative (PD) controller. The resulting control architecture is shown in Figure 1. Two integration tests are conducted under near realistic operating conditions using a feed pressure of up to 200 bar and distilled water as a propellant substitute, allowing the controller performance to be evaluated under representative system dynamics.

Conclusion: The physics-based whitebox model reproduces the measured tank pressure dynamics with similar dynamic behavior across varying input. However, deviations in magnitude remain, as seen in Figure 3. The data-driven blackbox NLARX model shows good accuracy only for input conditions similar to its training data. When different input cadences are introduced, the NLARX model shows significant deviations from the measurements, highlighting the limited generalization capability of blackbox modeling for highly nonlinear systems. In contrast, the whitebox model appears more promising, as it captures the overall system dynamics and allows parameter tuning to better match the real system. Experimental testing on the ground test station demonstrates that the implemented controller is

capable of regulating the propellant tank pressure under near realistic conditions with pressurant feed pressures of up to 200 bar. However, all integration tests consistently show a pressure overshoot in the range of 10 to 30 percent. This overshoot reflects limitations imposed by the system dynamics, valve actuation speed and the binary actuation of the DPR valve. The observed control behavior indicates that further controller refinement is required to improve transient performance and stability under more aggressive operating conditions.

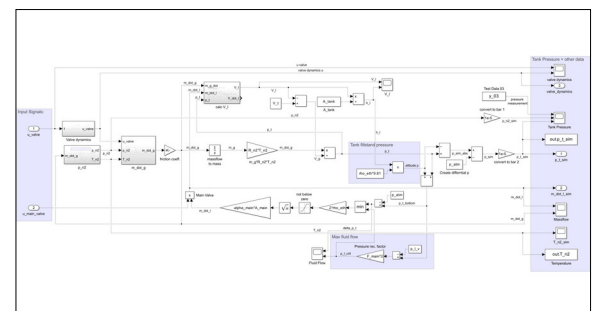
PSS of the Bi-Liquid pressure-fed Rocket and Injector Control Architecture with Safety Override for Tank Pressure

Own presentation



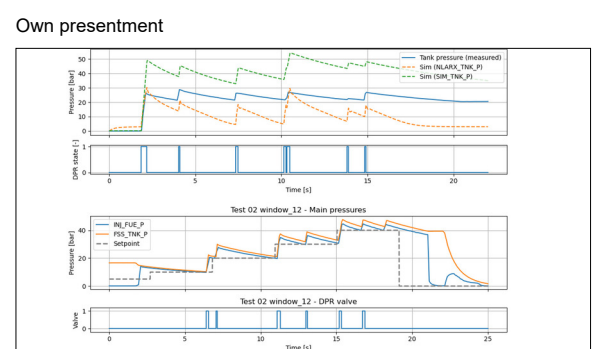
Simulink model for tank pressure simulation using DPR valve position as input

Own presentation



Comparison of measured tank pressure with whitebox and blackbox models top, and final controller test measurement

Own presentation



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Subject Area

Automation & Robotics, Simulation Technology

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